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Evaporation Records in Illinois

by

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The more one studies the subject of evaporation from water surfaces, the more one realizes the complexity of the problem. About ten years ago when I started this study, I asked a professor of agriculture how much water was evaporated or transpired from one of his corn plots. He answered, "Tons and tons of water." "But how much actual water loss is there in a given period?" I asked, and he replied that although he had studied the subject during the whole of his professional life lie still did not have an answer to that question.

If the problem is so complex, why do we bother trying to obtain evaporation records? The answer is that no matter how inadequate the data may be, scientifically determined records are of value, and those interested make use of these records.

The average annual rainfall measured at about 175 stations in Illinois is 36.62 inches. This amounts to 99 billion gallons per day. The water that gets into streams and lakes can be measured through stream-gaging installations operated by the U. S. Geological Survey office in Champaign. But, on the average, these gaging stations measure less than 25 percent of the original precipitation.

What happens to the rest of the water? Some of it soaks down into the earth to become part of our groundwater supply. Studies indicate that this is only a very small fraction. Some soaks in and reappears as stream flow. The rest of it is lost through evaporation or more correctly evapo-transpiration. This paper considers only that part of the loss that is evaporated from the water surfaces. This loss is of great importance to industries using surface water sources, to municipalities depending upon surface water reservoirs for their local water supply, and especially to farmers depending upon farm ponds for their water supply. During the last four years there has been great interest shown in irrigation equipment for increasing the yield of certain Midwestern crops. Knowledge of evaporation rates is very important for the irrigator. Such knowledge will help him determine when to irrigate.

How ARE DATA COLLECTED ?

Nearly all of the published Illinois evaporation records[1] are obtained from "Class A" U. S. Weather Bureau pans. These pans measure 48 inches in diameter and 12 inches deep. They are filled to within 10 inches of the top and water losses are measured with a hookgage inserted in a still well within the pan. Observations are made once daily, usually at 7 :00 A.M. Central Standard Time. An anemometer is located adjacent to the pan and measures the total amount of wind passing over the pan in a clay.

Evaporation records are collected at four Class A pan stations and on an experimental basis at three installations in Illinois.

[1] Climatological data, Illinois section, U. S. Weather Bureau.

One of these, located for a 12-month period at Fox Lake near Charleston, made use of sling psyehrometers to determine the vapor pressure gradient from the surface upward approximately 20 feet. Using these data with the Meyer formula[2] gave a rough measure of evaporation for that part of the lake. These measurements were discontinued because of lack of personnel at the lake.

In cooperation with the University of Illinois Civil Engineering Department, the Water Survey maintains an evaporation station on the engineering campus at which vapor pressure gradients are measured automatically with instruments known as Foxboro Dewcels. This instrument gives automatically the same type of data obtained by sling psychrometers. The cells give direct dewpoint readings whereas the sling psychrometers gave temperatures from which the dewpoints may be determined by use of Marvin's or other psychrometric tables.

A third experimental station is maintained at Four-Mile Crib in Lake Michigan. At this station a Serdex Mierohygrograph located 30 feet above the lake level gives very accurate relative humidity readings, which when combined with air temperature readings may be transferred directly to vapor pressure readings. Attempts have been made to utilize the material thus obtained for measuring evaporation at this location in Lake Michigan. However, it is obvious that a great many such stations would be needed to make an accurate evaluation on evaporation over so large a water area.

2 Meyer, Adolph F., Evaporation from lakes and reservoirs: Minnesota Resources Commission, 1942.

From the point of continuous operation, the oldest evaporation station in Illinois is operated by the U. S. Weather Bureau at Springfield. The records began in May 1941. The three evaporation pans operated by the Water Survey in cooperation with the Weather Bureau are located near Rockford in northern Illinois, on the engineering campus at Urbana, and at Carbondale in southern Illinois (fig. 1).

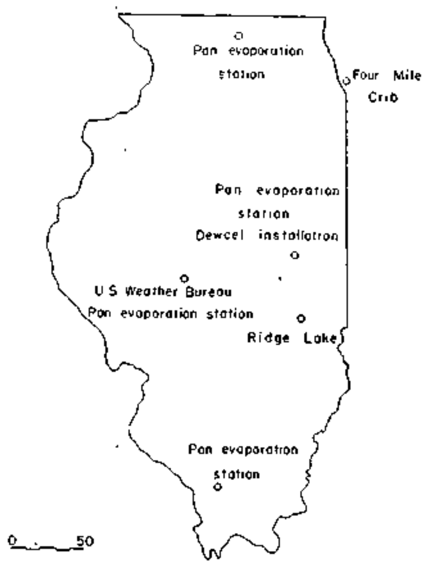
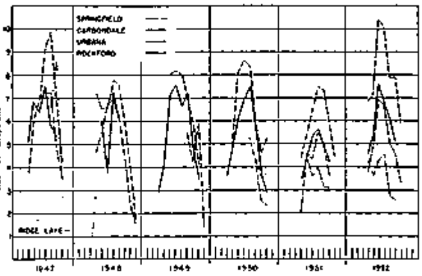


FIG. 1.—Evaporation stations in Illinois.

WHAT DO THE DATA SHOW?

Figure 2 shows the monthly evaporation for four pan evaporation stations, from March 1947 to November 1952. Maximum evaporation generally occurs during July, with the reported exception of 10.40 inches at Springfield in June 1952.

Minimum monthly totals are not significant because pan-type stations cannot be operated properly during



Fro. 2.—Pan evaporation measurements at four Illinois stations.

the winter months when evaporation is relatively low. The record at Ridge Lake, shown on the left side of the chart, indicates the magnitude of evaporation (or sublimation) to be expected during an Illinois winter.

The average annual evaporation for the 12-year period, 1941 through 1952, at Springfield is 48.59 inches. During the six-year period, 1947 through 1952, Carbondale had an average annual evaporation of 35.46 inches and Urbana 35.05 inches. Rockford, with only a two-year record, has 18.01 inches.

Longer periods of record are necessary before comparisons of evaporation can be made on a latitude basis.

Figure 3 shows typical temperature gradients in a Class A evaporation pan. During the early morning hours the water temperature is uniform vertically. Air temperature changes precede heating and cooling of the pan water by approximately two hours on both the ascending and descending limbs of the chart. The rate of rise or slope in water temperature closely parallels the air temperature elevation and is relatively steep. Pan cooling takes place slowly with a low value appearing before

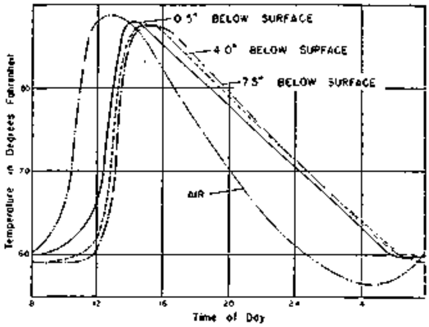


FIG. 3.—Typical temperature gradients in Class A evaporation pan.

dawn. Insolation causes a rapid rising of the surface temperature. Heating of the deeper water is slower, especially when there is no wind to cause mixing. When the surface water has reached its maximum daily temperature the lower layers continue to take on heat. After the maxima have been reached, cooling throughout the pan is uniform although the bottom water continues to be slightly warmer until morning when the gradient disappears. There was close agreement between shaded and non-shaded sets of thermometers except for the top half-inch layer. This incidentally is a mean relationship rather than any specific case. The effect of sunlight below the top one-half inch was apparently not significant.

Interpretation of Data

Many authorities have commented on the differences between lake evaporation and evaporation from a pan of water. Pan measurements even when taken near the margin of the lake or from a pan on a raft floating on the lake do not correctly represent the average evaporation for the whole lake surface. Temperature and wind affect evaporation. Because of these differences actual evaporation from a lake surface is usually less than that measured in an adjacent pan. Horton[3] believed that the most reliable method of determining the evaporation from large lakes was by calculation, of data on wind and temperature rather than from evaporation pans. Those that have followed him in study of the Great Lakes have believed that evaporation from large bodies of water such as the Great Lakes cannot be accurately determined. Fortunately for us, the evaporation from the Great Lakes, although a large quantity, is relatively unimportant in the field of water supply.

The formula developed by Horton is very similar to the one mentioned earlier by Meyer. The Meyer formula is:

$$E = C\ (V_w - V_a)\ (1 + W/10)$$

In this formula the evaporation is stated in inches per month and the V_w and V_a are vapor pressures at the surface of the water and 25 feet above the surface. C is an empirical constant dependent upon time, size and character of the water body. W is the wind velocity in miles per hour. Meyer made many comparisons between observed pan evaporation and evaporation computed by means of his formula. Whenever meteorological data, even reasonably suitable for use in the formula were available, he found a satisfactory correlation between observed and computed evaporation.

The most significant recent research on the problem of investigations is reported in Circular No. 229 of the U.S. Geological Survey.[4] This is a study of evaporation at Lake Hefner which was carried on from April 1950 through August 1951, by the Bureau of Reclamation, the U. S. Geological Survey, the Bureau of Ships, the Navy Electronics Laboratory, and the Weather Bureau.

Lake Hefner is a water supply reservoir owned by the city of Oklahoma City. The lake is formed by a long horseshoe-shaped dam located approximately eight miles northwest of the center of the city. The lake and its watershed have several characteristics which make possible a comprehensive study of four basic methods for determining evaporation from water bodies:

1. The water budget method, in which evaporation is determined by the difference between inflow and outflow plus changes in storage.
2. Use of evaporation pans.
3. The thermal energy-budget method, which takes into account all sources of incoming and outgoing thermal energy plus changes in energy storage.
4. The mass-transfer theory, which calls for the measurement of factors affecting removal of water vapor from a water body by the process of turbulent diffusion and transport.

The study group maintained three separate installations around Lake Hefner to provide data for the evaporation pan studies. Regular Weather Bureau Class A pans were installed at each site to indicate areal variations. Water levels in the pans were observed with hook gages, and attempts were made to continue observations through the winter.

The report states that daity pan evaporation at Lake Hefner could be accurately estimated from air tem-

[3] Horton, Robert E., Hydrology of the Great Lakes: Sanitary District of Chicago, 1927.

[4] Water-loss investigation. Lake Hefner studies technical report, vol. 1: U. S. Geol. Survey Circ. 229.

perature, solar radiation, dewpoint, and wind using an energy balance approach. The technique is now being tried experimentally with data collected in Illinois.

Prom February through April, 1953, the Water Survey built and placed in operation three automatic evaporation-recording machines. These are located adjacent to the evaporation pans located at Rockford, Urbana, and Carbondale. The instruments are modified Stevens weighing-bucket rain gages in which the bucket has been replaced by a flat pan having an area ten times that of the standard collector ring at the top of a standard rain gage. This permits a multiplication factor so that the full travel of the pen across the record chart indicates 1-inch of evaporation. The records from these gages are interesting in that they show when evaporation is greatest. This type of instrument should prove particularly beneficial when the temperature is below freezing. It should also prove of value in particular studies where daily measurements of water loss are not sufficient for correlation purposes and an hourly record would be more desirable.

It is only natural to expect that the standard pan measurements will be superseded by a formula which will require only a knowledge of wind and temperature in the area being studied. However, until such short-cuts are available we shall continue to collect water loss data by all practicable methods including the Class A pan.

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